# An Energetic Approach to Predict the Effect of Shot Peening Based Surface Treatments

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**This paper is a good example of the outstanding research being conducted in the Department of Mechanical Engineering at Politecnico di Milano. The university is the venue for the 14th International Conference on Shot Peening in 2020 and Dr. Mario Guagliano is the chairman.**

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## ABSTRACT
Almen intensity and surface coverage are well-known to be the defining parameters of shot peening based surface treatments. These parameters are directly affected by material properties, the extension of the contact zone, the geometry of the impact pair as well as impact rate and velocity. These intricate relations have resulted in often dissimilar predictions of shot peening effects even while using identical combination of Almen intensity and surface coverage. With the introduction of new generation of impact based surface treatments, there is a need to find a more widespread parameter that would facilitate direct comparison of all different treatments and relate the main process parameters with the resultant mechanical characteristics.

Herein, we propose to use an energy based parameter to describe the peening process as a more universal approach, which incorporates collectively the effects of Almen intensity, surface coverage as well as diameter, material, and velocity of the impact media. A set of finite element analysis was developed to demonstrate the correlation of peening process effects with this energetic approach. Comparison with experimental data also confirmed that the proposed method could provide a quite good estimation of the effect of peening parameters on the treated material.

## INTRODUCTION
Shot peening is a surface treatment mainly known for its favorable effects in enhancing fatigue strength of mechanical components. It has been widely used in machinery, aerospace, automotive industry and railway systems for decades. This process consists of impacting material surface with high velocity peening media (mainly steel shots or ceramic beads), to generate inhomogeneous plastic deformation and consequently induce compressive residual stresses on the surface layer of the treated material. With the advancement of technology and development of high tech equipment, the concept of shot peening, which is based on inducing plastic deformation with repetitive high frequency impacts, has been recently extended to a vast range of cutting-edge impact-based surface treatments. The new generation of surface treatments are developed to amplify the desirable effects of the conventional shot peening for a wider variety of applications ranging from classic industrial applications to biomedical ones. These processes can be listed as ultrasonic shot peening (USSP), high energy shot peening (HESP), surface mechanical attrition treatment (SMAT), surface nanocrystallization and hardening, severe shot peening (SSP), sandblasting and annealing, ultrasonic impact treatment (UIT) and ultrasonic impact peening, to name just the most noted ones. It is also to be underlined that some of these methods are basically using the same setup and mechanism and have been named differently due to the lack of consistency in the literature. Nevertheless, what all these methods have in common is the application of severe plastic deformation through high energy impacts to induce grain refinement, hardening, and compressive residual stresses through recurrent impacts of either shots, balls or pins using various loading schemes. Whatever the apparatus and loading arrangement, the obtained results are mainly influenced by a few parameters that all the aforementioned peening treatments share. The critical parameters are the indentation size produced by a single impact, which is in turn affected by impact velocity and impacting media's material and geometry, as well as the total exposure time; exposure time is the duration of the peening treatment when the target material is being impacted by the peening media. These factors are practically set through two pragmatic parameters used in conventional shot peening to control the consistency and facilitate replicating of the process, i.e., Almen intensity and surface coverage. Almen intensity is the industrial measure of the kinematic energy of the shot stream and is calculated by measuring the curvature of standard Almen strips exposed to shot stream at saturation point. Saturation point refers to the first point on the arc height vs. exposure time curve, where doubling the exposure time doses not change the arc height more than 10%. Although recognized as the universal parameter of shot

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peening, estimation of Almen intensity is not straightforward and necessitates the use of apposite Almen strip and Almen gauge. Surface coverage, on the other hand, is the ratio of the plastically deformed area to the whole treated surface area. Considering the exponential behavior of surface coverage over time, coverages higher than 98% (highest surface coverage that can be measured visually also known as full coverage) are estimated by multiplying factors to the time required to reach full coverage.

For a long time, many researchers have tried to provide empirical graphs, formulations and numerical simulations to relate these main process parameters with mechanical behavior of the treated material. There are few successful efforts regarding distribution of residual stresses, work-hardening and the induced surface roughness. However, most available approaches are either limited to specific sets of process parameters and limited materials or are applicable to a range of process parameters and thus cannot be straightforwardly generalized. Besides, Almen intensity and surface coverage themselves are associated with multiple process parameters. For example, surface coverage is directly affected by the interaction between the impact pair, their material properties, and the contact zone, which are in line affected by shot and target material geometry as well as mass flow and peening velocity. Hence, there are reports of obtaining different distributions of residual stresses and extensions of plastically deformed areas, using the same combination of Almen intensity and surface coverage.

Herein, we propose that rather than using a combination of parameters like Almen intensity, shot diameter, shot material, shot velocity and surface coverage to provide an inclusive estimation of the effect of peening parameters on the functionality of the treated material, a single parameter that is directly related to the impact energy can be used for this purpose. A finite element model (FEM), previously developed by the authors [14] and updated incorporating varying impact angles and implementing both single impact and multiple impacts, has been used to prove the concept of the idea. The suggested energetic approach entails the effect of all factors associated with the media stream including its size, material properties and velocity into one single parameter and has the potential to be generalized for any impact based surface treatment. A set of experimental test data, for which we had access to all the process parameters and residual stress distribution, were simulated by FEM analysis to check the prediction of the energetic approach and assess its validity.

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For more information on
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